SHELL FORGING METHODS FOR ARMY HIGH EXPLOSIVE SHELLS.

by

Dante R. Marzetta.

Thesis
M35946

[redacted]

SHELL FORGING METHODS FOR ARMY HIGH EXPLOSIVE SHELLS

January 30, 1946

Dante R. Larzetta
Lt. Comdr., U.S.N.

Library
U. S. Naval Postgraduate School
Annapolis, Md.

LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIF. 93940

CONTENTS

	Pages
INTRODUCTION	1-5
Object of Paper	1
Steps in Manufacturing of shell forgings	2-3
Comparison of Shell Forging Methods	4
SHELL FORGING, GENERAL	5-8
Problems in Shell Forging	5
Steel Used	6
Weight Allocation System used in Wartime	7
ONE SHOT PROCESS	8-10
HYDRAULIC PIERCING AND ELONGATING	10-18
Variations in the Process	11
Methods to Prevent Eccentricity	
Slugging of Billets	12
Use of Guide Ring	13
Use of Split Dies	13
Shape of Cross Section of Slug	14
Formula for finding Size of Slug	14
Use of Draw Rings for Elongation	15
Elongationg by Cross Rolling	15
Profile of Draw Rings	15
Spacing of Draw Rings	16
Shape of Mandrel	17
Use of Roller Dies for Elongating	17
Prevention of Perforation of Shell Base	17
Pierce Bottom and Draw Process	17
MECHANICAL MACHINES FOR PIERCING AND DRAWING	18-21
Types of Mechanical Machines	18
Overloading of Mechanical Machines	19
Problems ofEccentricity	19
The Bulldozer	20
FRENCH EXTRUSION METHOD	21-22
PROGRESSIVE PIERCING OR UPSETTER METHOD	22-28
Applications of Process	22
Steps in the Process	23
Variations in the Process	24
Forging without a collar	25
Forging with a collar	25
Springing of Dies	25
Salt Shaker Punch	26
PIERCE HAMMER AND DRAW METHOD	28-30
REVIEW	31

7370

SHELL FORGING METHODS FOR ARMY HIGH EXPLOSIVE SHELLS

Introduction

With the entry of the United States in World War II, one of the many pressing problems was obtaining the necessary supplies of shells for the U. S. Army. Companies, large and small, were given orders to produce shell forgings. In most cases peace-time machinery was converted to war-time production; in some cases new machinery was obtained. In all plants, however, many problems arose which presented a challenge to the industry. In order to make a comprehensive study of the forging of shell steels and all its ramifications, the War Department detailed a special research committee of the American Society of Mechanical Engineers to make a thorough investigation of the problems and methods of making shell forgings with the aim of disseminating the resulting information for the good of all concerned so that problems could be overcome, methods improved, steel saved, and production increased. The report of the committee is an exhaustive report covering all phases in the forging of shells including forging methods, stell selection, forces required, and costs of production.

This paper is essentially a review of the various forging methods employedby the industry in the manufacture of Army 75 mm., 90 mm., 105 mm., and 150 mm. high explosive

shells as reported in the special committee report to the War Department.

In order to obtain a clearer picture of the general flow of materials in producing shell forgings, a brief review of the usual processes is discussed.

The first problem is the selection of the steel to be used. The actual composition of the steel, as seen later, was specified by the government, but a further problem must be solved in deciding what size and shape of steel stock is to be used. In some cases round bar stock is used; in others square sectioned or squaresectioned with bevelled or rounded corners is used. The cross section selected depends upon the size of the shell forging made, the cost and availability of the various shapes, and the type of forging and heating equipment available. Close tolerance round bar stock was preferred but it was more expensive and was difficult to obtain on the open market. Round cornered square stock was used in many cases.

Having received the steel selected the manufacturer had next to cut it up in small sections called slugs for the making of the forgings. In the case of the smaller shells the long bar stock was heated at one end, forged, and then the forging cut off from the remaining bar stock which was again heated for another forging. In most cases,

however, the long bar stock was divided into so-called slugs. One or two slugs depending on the shell size, contain enough steel for the forging. The process of cutting off these slugs is known as billet separation. Many methods are used. In some cases the slugs are sheared off, sometimes sawed, sometimes cut off with torches. Another prevelant method is to nick the bar stock at the proper length either mechanically or with a torch. The bar is then placed under a press where the slug is broken off. Again, the method used depends on the facilities available and the costs of the different methods. No method has all the advantages.

The next step is to heat the slugs to forging temperature, about 2300 degrees F. The problems here are manifold and include proper temperature control, uniformity of heating, precautions against overheating and excessive scaling. Many types of furnaces are used; some have rotating hearths, some have inclined hearth bottoms, but in all cases care must be exercised in this stage of operations.

Following the heating the slugs are descaled, either manually removing the scale with a scraping tool or using mechanical scrapers.

After descaling, the slugs are forged. The various forging methods in general use are described fully in the body of this paper.

The forgings are then cooled and inspected. Those that pass inspection are then given a nosing operation and then sent to the machining company where the shells are rough and

finished machined. The shells that fail inspection are "hospitalized" if possible, that is, salvaged if the defects are slight.

As will be seen there are a great variety of methods employed in the actual process of forging the shell blanks. Just what method is used again depends on the many factors involved, such as the machinery available, the economics of the problem, and the experience of the company. It is difficult to say which method or combination of methods is best, since what is best for one type of shell may not be best for a different type shell. Furthermore, the ability to convert the machinery back to peace-time production is an ever important factor to the manufacturer.

For the smaller shells(75mm. and 3" A.A.) the upsetter method and the French extrusion method appeared to be the most economical. For the 90mm. shells the automatic progressive pierce and draw method appeared cheapest. For the 105mm. the pierce and draw method was best. In the case of the 155mm. shells the one shot process was by far the most economical. Thus it is quite evident from the findings of the committee that no one method is the best for every case. One fact, however, stands out significantly and that is the ability of the American producer to adapt his existing equipment to the production of ar material. The methods to be described were all successfully employed and reveals again that there is more than one way to do the job.

Shell Forging, General

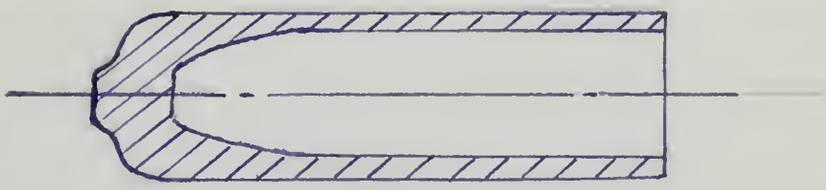
Generally speaking, the forging of shells appears simple enough for all it amounts to is forcing a punch into a heated slug which is held in a die. There are, however, many attendant difficulties which plague this simple process. The cavity may be eccentrically placed, the shells may stick in the dies, the punch may stick in the shell, the forging may not have completely filled the die, or the punch and dies may break or wear out rapidly.

To obviate these difficulties various remedies appeared. High alloy steels were used for dies and punches, punches and dies were indexed, dies were made with removable conical bushings, shell ejectors were designed to eject the shell from the die, lubrication of die and punch was tried, better heating of the slugs before forging was practiced. A few producers made the finished product from one single forging operation called the "one shot process", but most of the others accomplished part of the forming operation in the forging press which gave an intermediate product that had to be further elongated by pushing this semi-finished blank through a series of draw rings or rollers on a so-called draw bench. This is the so-called "pierce and draw" process. There are many variations to the above methods, but the principles are the same. Some machines are hydraulically, others mechanically operated. Some have vertical piercing presses others horizontal.

During World War I there were so many unsolved problems attending shell forging that in general the cavities had to be finished machined. The present forging practice, however, delivers the shell forging with a forge finished cavity which meets the specifications as to dimensions and finish.

Some efforts have been made to make centrifugally cast shells but the method is apparently too expensive.

The general shape of the forging is sketched below.



After the forging operation is completed the forging must be nosed and its exterior machined to final size. The steel used in these forgings was, up until about the middle of 1943, the SAE X-1340 steel of the following composition: carbon, 0.35-0.45; manganese, 1.35-1.65; phosphorous, .045 max.; sulphur, 0.075-0.15 per cent. This steel was a high manganse, high sulphur steel which, although it led to such forging difficulties as eccentricities, longitudinal cracks, and red shortness, did have free machining qualities. In an effort to save the stock of alloys and in order to meet higher specifications as to physical properties a new steel was introduced in mid 1943 designated WD35-3 (War Department Special Steel). Its composition was as follows: carbon, 0.60; manganse, 1.00 max.; phos.,0.055 max.; sulphur, 0.06 max.;

silicon, 0.15-0.35 per cent. Residual alloys in this steel were not to total over 0.50 per cent, and were allowed as follows: nickel, 0.35% max.; chromium, 0.30% max.; and copper, 0.25% max. This steel reduced the use of manganse and sulphur. The desired strength and other properties in the steel were obtainable by heat treatment. The substitution of WD3S-3 for X-1340 led to no particular difficulties in the forging operation and heat treatment, but did lead to considerable trouble in the machining operations. The change led to an immediate slump in production. Retooling at the machining lines finally regained about half of the losses in production so that by the ind of 1943 production was still 5-15% below what it was when X-1340 was used.

Besides the saving of alloys a program was also carried out to save steel by the use of a "weight allocation" system which aimed at limiting the maximum permissible weight per forging including the weight of steel which was not converted into shell forging. Not all methods of forging were able to stay within these limits which were very close and demanded good production control and practice. For example, in the case of the 90mm. shell the allocated weight for bar stock was set at 30 lbs. Where the producer did the forging only and then sent his product to another factory for machining the average weights of forgings by different methods was as follows: Upsetter, 33#; Pierce and draw,32.67#; other methods, 33.0#. If the forging and machining were done at the same plant cooperation between departments was better and in this

the plants were able to stay inside the allowed limits with averages between 27 and 28.83 lbs. for the finished forging. The same situation was generally found in the case of 75mm. and 155mm. shell production.

Other methods of saving steel were used such as buying the steel in multiples of slug weight thus eliminating end scrap, and by better nosing procedure in the case of 155mm. shells.

With this background of the general problems to be met in the forging of these shells and of the steel used we are ready to proceed with the various methods of manufacture. These may be roughly classed as follows: the one shot process, hydraulic piercing and drawing, mechanical piercing and drawing, the French extrusion method, progressive piercing or upsetter method, and the pierce hammer and draw method.

The One Shot Process

As the name of the process indicates, the forging is completed in one operation. The process had been tried unsuccessfully many times but has finally been perfected. At the time of the report (1943) only one producer in the U.S. and two in Canada were using the process.

The method became successful when extrusion (the flow of metal in the opposite direction to that of the punch) was eliminated. It was this backward extrusion which increased the piercing pressure excessively due to friction that had previously caused the failure of the process. Furthermore,

it is also known that the use of a long slender punch (as is required in this process since the shape of the punch must be that of the finished cavity) requires greater piercing pressures since more extrusion generally takes place. To defeat this tendency toward extrusion the vertical forge press was so designed that the die bushing was axially fixed but the die base was allowed to recede whenever the force on it exerted by the punch exceeded a certain adjustable value.

The Canadian presses use four indexed punches (use of four punches in rotation; while one is in use the others are being cooled and lubricated) fitted with removable punch tips for ease of replacement. A piston in the bottom of the die which receded was capable of being adjusted to variable settings before recession began. The setting must be adjustable to account for differences in the shell material and different roughnesses of the die due to wear. The Canadians use a forging temperature of about 2200 degrees F. which requires higher pressures than those in the U.S. where higher temperatures are generally used. The penetration is in the order of six punch diameters. The die is a split die so it can be opened for shell removal.

The American process is similar except that a different means of controlling the time of die bottom recession is used and that the die (cast iron) is, when first installed, so designed that it has four longitudinal saw cuts on the outside of its cylindrical surface. After use the die breaks longitudinally into quarters permitting shell ejection.

This procedure, however, produces four longitudinal, scarcely visible overfills in the forging.

The U.S. method also uses a collar at the top of the forging so that the forging is definitely in tension; this reduces the pressure on the die bushing and supposedly improves the concentricity. No collar is used in the Canadian system, although here also the forging is in tension since the top of the die grips the forging very tightly.

In the U.S. method a further operation must be performed on the forging after it leaves the one shot press; that consists ofsetting the bottom in another press. Technically then, the U.S. process is not really a one shot method even though only a small deformation occurs in the second press.

The slug used in the Canadian press is square sectioned. The halves of the die are clamped over the slug by means of hydraulically driven wedges. In the American press the slug used is a square with rounded corners. In both presses the shaped of the slug changes from square to round as the punch penetrates.

Hydraulic Piercing and Elongating

In general this method which was the primary method used in World War I consists of forcing a punch into a round or square sectioned slug which produces a cup in the slug. The slug is then forced, by means of a mandrel, through smaller and smaller die rings or other elongating machinery so that it is lengthened and reduced in diameter.

The process is by no means standardized; there are many variations including:

1. The punch enters from above.
2. The punch enters from below.
3. The slug is cylindrical.
4. The slug is prismatic, i.e. square sectioned with rounded corners.
5. The slug is square sectioned with rounded corners but tapered in length.
6. The cup produced is short and thick requiring great subsequent reductions.
7. The pierced blank is almost finished, requiring little subsequent reduction.
8. The die bushing is cylindrical.
9. The die bushing is tapered.
10. Previous to piercing the slug is driven hard into the bushing; i.e. it is slugged or squashed.
11. In the slugging process a cavity may s metimes be made to guide the piercing punch.
12. The punch is centrally held by a pilot ring.
13. The punches are indexed.
14. Punches ad die bushings are indexed.
15. The punch and or the mandrel are water cooled inside.
16. Drawing is done in ring dies.
17. Drawing is done in roller dies.
18. Elongating is accomplished by cross rolling.

In this process the slug is pierced in a vertical press. Usually the punch descends on the slug but the reverse is used

in some cases since it is claimed that better concentricity and freedom from scale result. One of the biggest problems in shell manufacture is the avoidance of eccentricity of the shell cavity.

In the case where the punch enters from above several procedures are used to hold the slug in a central position so as to avoid eccentricity. One of these is to fit the slug into the die bushings as closely as the rolling tolerances permit; this requires dies of little or no taper. Another method is to use split dies. Another method consists of slugging or squashing the hot billet prior to piercing so that the upper end, at least, of the slug is then expanded in cross section and fits the die snugly. If the forging is to be boat tailed then the slugging operation also squashes the corner of the slug into the boat tail and thus holds the base central also. The slugging also levels of the top of the slug which if inclined may deflect the piercing punch. The slugging may also be done to give a flat surface or to make a small cup in the top of the slug to guide the piercing punch. After slugging the tools are usually indexed to bring the piercing tools into operation. If the press is not so designed the slug may have to be transferred to another die or the tools changed. The press may be designed to slug partly or to slug completely although in the latter case high pressures and back flashing are encountered. Mechanical presses should not attempt complete slugging for the case of

slightly overweight billets the pressures resulting may ruin the press.

The use of slugging, though ensuring better concentricity, requires greater subsequent piercing pressures, reduces die life since the slug is in the die longer, and reduces the life of the punch on the slugging tool due to the scoring caused by the flow of metal under high pressures around it.

Another method used to center the slug and the punch is to use a guide ring or pilot cover which is placed in position manually in small presses. The guide ring is centered by the die bushing and holds the top of the slug in a central position. The ring has in it a guiding hole for the piercing punch. The thickness of the ring is such that the cylindrical portion of the punch is in contact with the close fitting hole of the guide ring before the punch begins to enter the slug. This prevents any sidewise motion of the punch which would cause eccentricity even though the slug was held centrally. Where large presses use rings so large they can not be placed manually they may be suspended by chains so as to rise up and down with the punch which they surround.

The size of the slug used with the guide ring and the size of the ring itself are critical when non squashed slugs are used or else the slug will stick in the guide ring.

A still another method of holding the slug central which can be used only on very rigid machines is to use split cylindrical die bushings which can be clamped over the rough edges of a slug and squeeze them into concentric position if the slug has been uniformly heated.

In some cases round cylindrical slugs are sued but in most cases square sectioned slugs with rounded or chamfered corners are used. The round slugs extrude more and cost more but are more easily heated, produce less scale per unit weight, are more easily centered, and produces more uniform wear on the die bushing. When using a round slug the flow of metal is such that it first fills up the small clearance in the die and then begins to extrude or flow back against the punch with consequent high pressures on the die and punch. In the square slug the attempt is made to have the metal displaced by the punch fill up the die so that the end product is completely forced into all parts of the die. Actually the metal flow is as follows: the slug is first shortened until enough friction is created to hold it in place; it then proceeds to fill up the die and finally near the end of the stroke some extrusion occurs. The size of the maximum round cornered square to use so as to just fill in the die can be determined from the following formula which is usually used as a guide only:

$S^2-3.222rS + 2.45r^2 = 1.375d^2$ where,

S is the length of a side of the square

r is corner radius of the slug

d is the diameter of the piercing punch.

The shape of the billet was changed from the first used square billet to a round cornered or bevelled cornered square so as to prevent laps and seams in the forging.

After the intermediate blank is pierced it is elongated by forcing it by means of a mandrel through a series of draw rings each somewhat smaller than the preceding. The operation reduces the diameter of the blank as well as elongates it. In some cases roller dies are used instead of the ring dies. In a still different process a cross rolling mill is used to effect the reduction and elongation.

In the latter process three driven humped rolls are used as an adaptation of the seamless tube drawing process. Each roll is set so that its centerline, if it were located in a plane defined by the center of the roll and the center of the mill, would be offset about 7 degrees with the centerline of the mill. Each roll is turned 3 degrees out of and at right angles to that plane. The reason for this is that this skew sets up frictional forces, which feed the blank forward. Thus, in this method, the force exerted on the mandrel is less than in the other methods. The entrance cone angle of the rolls and the axial position of the rolls is very important and must be held to close limits.

In the case where ring dies are used, the profile of ring is also of great importance. A long taper of 10 degree angle, say, would cause excessive friction. Likewise, a short taper with a 25 degree cone angle, say, would set up less friction, but would require more deformation with liklihood of te aring.

0470

A cone angle of 15 degrees or thereabouts is generally used. The shape of the ring profile will also vary if the work is hot or cold, the latter producing much higher friction forces. Schneider of Creusot in 1921 recommended a die ring profile which is the arc of a circle whose radius is 7 1/2 times the radial distance to be drawn off by that ring. The generally used shape of profile has a short entrance cone angle, a short usually 3/8" cylindrical section, followed by an exit cone angle, which is designed to protect the edges of the cylindrical section from breaking.

The draw rings may be spaced so that the blank may be in only one ring at a time, or so that it may be in two or more rings at the same time. In the first case less force is required to push the blank through. In the second case, however, though more force is required, there is a tendency to reduce eccentricity and to prevent the running ahead of the blank in front of the mandrel. The temperature of the blank should be equalized in order to prevent irregular drawing due to temperature differences in the blank. It is preferable to have the plane in which the draw ring touches the shell blank (1st pass on a boat-tailed forging) be where the radius of the cavity joins the taper. The reason for this is to permit the entrapped gases in front of the mandrel to escape past the mandrel. If the ring is placed farther back the gases do not escape, and the ensuing gas

pressures may be sufficient to cause so-called "balloon cavities" or even running ahead. In succeeding passes running ahead can be eliminated by lubricating the cylindrical part of the mandrel and thus facilitating extrusion, and by having the blank start into the succeeding ring before it leaves the one it is in.

It is to be understood that the shape of the mandrel is decided by the specifications for the cavity.

Roller dies are used since they produce less friction and hence last longer, but running ahead is more difficult to control. In general, the same considerations apply as in the case of ring dies. Roller dies generally produce longitudinal flashes or fins on the blank which are easily removed in the finishing pass by a regular draw ring or another roller die.

One trouble must be constantly guarded against during the drawing process and that is punching the mandrel through the base of the shell. This is usually prevented by water spraying the base of the shell, cooling it off, and thus hardening it.

In a variation to the preceeding methods of piercing and then drawing called the pierce-bottom-and draw process no water is used. The slug is first pierced a little less deeply than in the regular pierce and draw method. The blank is removed and descaled by turning it upside down and spading

it or hitting it against a stop. The blank is then placed into the bottoming die of a second press which is centered by a cone where it is pierced still deeper. The bottoming die, which is water cooled by removal and immersion in water between strokes, cools the base end of the shell and thus prevents subsequent perforation. On the upstroke the piercer carries the blank with it, the bottoming die is removed, and then acting as a mandrel the piercing punch descends again to push the blank through a set of draw rings to complete the process. The method is not used for shells larger than 105 mm. because of the difficulty of removing the bottoming tool after each operation.

Mechanical Machines for Piercing and Drawing

In the previous section hydraulically driven piercing presses and draw benches were discussed. There are cases where a mechanical piercing press is used with a hydraulically driven draw bench; likewise, the reverse combination is also found. Then too, there are some plants using purely mechanically driven forging machines in the pierce and draw method. Six plants were using such a system in the U.S. at the time of the report (1943).

Most of these mechanically driven forging machines were in the horizontal position. Some of the machines used a continuous, slow, reciprocating motion of the forging tools, whereas in the others there was a pause between each forging stroke soas to permit shifting the blank from one die to the next,

or to permit the machine to index a movable blank holder from one position to the next. Where a continuous stroke was used the motion had to be slow enough to permit these change overs.

The forging principles and methods are essentially the same whether hydraulic or mechanical piercing is used. The mechanical press, however, usually using an electric motor and flywheel arrangement, exerts more force at the end of the stroke than in the middle of it. This feature adapts them well for the progressive piercing method where each succeeding punch penetrates more deeply. A strong enough machine can complete the piercing in one stroke.

Hydraulic machines generally stall if an overload is created, but a mechanical machine will tear itself apart under similar conditions unless fitted with overload safety devices. These devices generally consist of a connecting rod which will buckle or a bolt that will break and thus stop the press before any damage ensues in case of an overload.

As mentioned previously, most of the mechanically driven presses are horizontal. The problem of eccentricity thus becomes very important since the bottom of the die wears very rapidly due to the slug resting on it and also because the scale collects there and increases the wear. The usual means of improving ~~xxxxxxxxxxx~~ the concentricity is to slug the blank or to use split dies. These were

discussed previously and need no particular amplification. Another method to ensure better concentricity is to guard against differential expansion between the punch carrier and die block due to differences in temperature. The die block is usually water cooled to reduce this differential expansion.

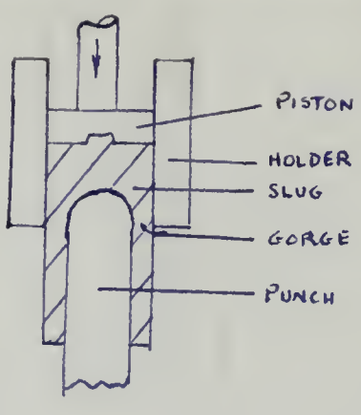
The procedure in the making of the shell forging is similar to that previously described. The slug is first squashed and cupped for centering, then pierced to the desired depth depending on the capacity of the machine. The blank is then finished by pushing it through draw rings by means of a mechanically driven mandrel.

An interesting type of mechanical forging machine is the so-called bulldozer, which is essentially a slow moving crank press with usually horizontal crossheads. The crosshead is usually wide enough to accomodate two forgings at the same time; thus the machine can keep two forge lines going. Here again, the differential expansion between the punches and die block must be counteracted by water cooling the die block, or by heating the die block to its operating temperature and setting it in alignment with the punch. The die bushings are generally of small taper so as to get more uniform work on the blank when it is forced through the die rings (actually only one draw ring is used). Since the die bushings wear quickly they must be replaced frequently to ensure concentricity.

The steps involved on each blank in this process are generally as follows: (1) The round or square slug is squashed and cupped in the first die. (2) The blank is manually moved to the next die alongside the first where it is partially pierced by another punch. (3) The blank is again manually moved to a third die bushing alongside the second where the piercing is completed. (4) Finally the blank is placed on a mandrel where it is forced through a single draw ring to complete the shell forging.

French Extrusion Method

This process though quite simple and efficient is not much used perhaps due to the fact that machine builders have never made parts so that presses could be adapted to this process, and because of lack of information on controlling, the dimensions of the extruded blank. The process consists in actually extruding the metal; i.e., forcing it through an opening (not to be confused with extrusion as used before where metal in a die flows in a direction opposite to that of the punch). Schematically the process may be indicated as in the sketch below:



The slug is placed in the holder or container. A piston then enters the holder and exerts pressure on the slug causing the flow of metal through the gorge and over the punch. This method reduces die friction considerably. There is no control over the outside diameter other than the relation between the punch and holder which therefore is critical and must be maintained.

In actual practice the method was observed in use on a bulldozer, which had been adapted to the method. The operation was similar to that described for the schematic sketch except that the piston of the sketch became a stationary abutment, and the punch and holder did the moving. The nose of the piercing punch was made flat because the round punch gathers scale and steel. The bottoming, or second punch used, was made with a round head.

Progressive Piercing or Upsetter Method

As the name of the process indicates, the forging of the shell blank is carried out so that only a part of the length is pierced at one time while the rest of the length is firmly held in split dies. The process, therefore, generally involves four to six steps before the blank is completed. The process is well adapted to 75 mm.and 90 mm.shell production though it has been used on shells up to 155 mm. size. In making the larger shells a single slug with a tong hold is used, whereas in the case of the smaller shells a round

bar with a length of two or more slugs is used. Square bar stock is used in some cases, but generally round stock is used.

The method was developed at the Frankford Arsenal in the early 1930's. Since the forging machines, which were adapted to this method were originally designed to forge a head on a bolt by upsetting, the name "upsetter" for the process has been carried over. Similarly the size designations of the machines have been carried over. Thus a five inch upsetter was one which could forge a head on a red hot five inch round bolt.

The method consists in first applying a preliminary upset usually coupled with a short centering pierce; the upsetting is then followed by a series of deeper and deeper piercings. The blank is then trimmed and given its last sizing and shaping.

The usual forging machine is electrically powered and usually holds working dies and tool holders large enough to give four or six forging impressions. The forging is transferred to the next die after completion of operations in a given die until all steps in the forging have been completed. The dies are split and at the beginning of a cycle are automatically closed by a quick-acting cam., the dies grip the billet prior to forging. At the end of the cycle the dies are automatically opened as the piercing punch is retracted thus permitting easy transfer of the blank to the next die

and operation. The usual machine can give 25 to 35 working strokes per minute when idling (i.e., not actually forging). A complete cycle would be as follows:

1. The cam activated dies close and grip the billet.
2. The tools and holder enter the die; one tool displaces the hot bar into the die impression.
3. The tool holder and tools return to the normal at rest position.
4. As the tools return the dies are opened, the dies end up in the open position.
5. The blank is removed and transferred to the next die.
6. The above cycle is repeated.

The process finds two variations in industry. In one case the forging is made without a collar. In the other case the forging is made with a collar.

The method of forging without a collar is slightly more economical in the use of the metal since no collar is formed, which must later be trimmed off, however, more skillful operators are required. Even then bad forgings are often produced. For that and other reasons,in the later stages of World War II, this method was discontinued for the production of Army shells. Other disadvantages of the system included irregular forgings, difficulty in stripping, and excessive die wear. This excessive die wear resulted when the piercing of the hot bar was followed by metal flowing ahead of the punch filling up the die and causing the balance of the stock material to extrude (flow opposite to direction

of piercing) causing excessive die wear and irregular stock distrubition.

In order to eliminate the extrusion noted above forging with a collar was adopted. The method produced better results with less skilled operators. Usually the first pass consists of two blows. The first blow generally loosens and splinters the scale and forms a bulbous upset end. The second blow follows after the billet is rotated 90 degrees. This blow forms a collar on the forging.

Since the final volume of metal in the shell is dependent on the original volume of metal, the size and shape of the first upset are considered most important since this die must be completely filled after the first pass. As the die wears the volume changes. This must be allowed for by increasing the volume of metal by changing the stock gage setting, or by changing to a punch with a smaller plug or center to allow for the excess material in the die. Dies for the second, third, and fourth passes should be so designed that no overfills occur; in fact the second and third passes are designed to have a little underfill in order to prevent any extrusion. The last die is a close fitting, shaping and sizing die.

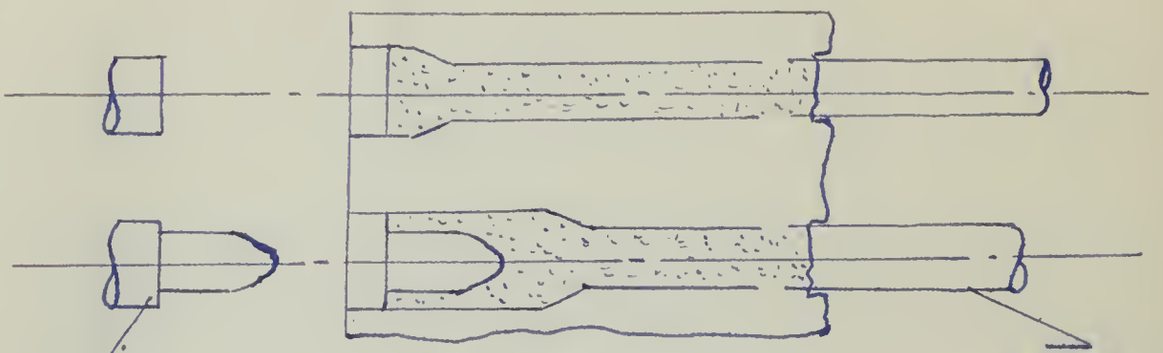
Sometimes the use of too light a machine for the job results in the springing (moving apart) of the split type dies due to the excessive pressures encountered in the last part of the working stroke. The result is an eccentric forging and also one with fins on it. Further more, the dies will come

together when the punch is retracted, thus making the forging oval in cross section. Other causes of an eccentric forging, which must be continually guarded against as in other methods of forging, are wearing of dies, oversized stock, misalignment of tools (due to temperature differences or mechanical misalignment) and work slides and toggles.

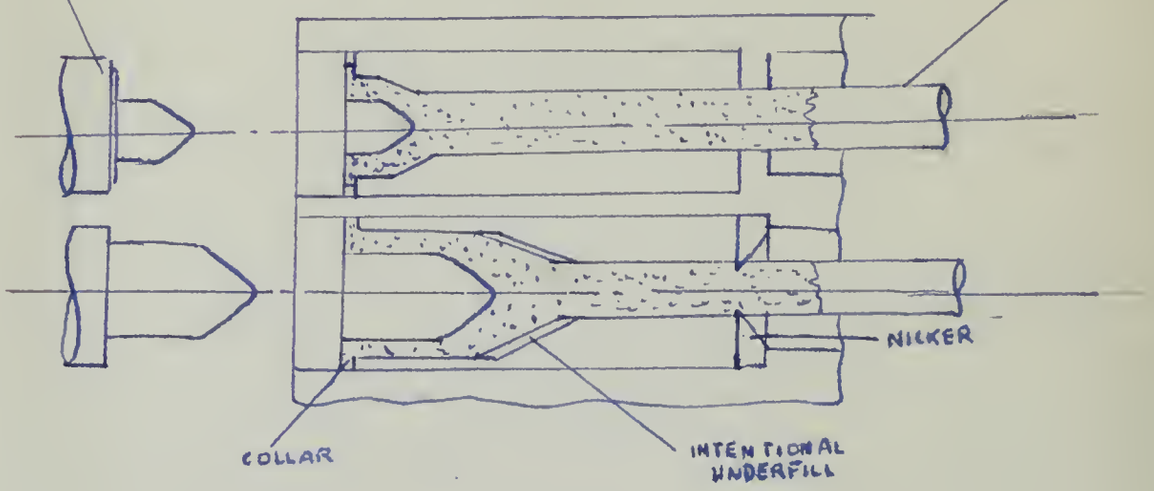
When round bar stock is used close-tolerance bars are used in order to getaway from continually readjusting the billet length in order to get the correct weight of metal. As a consequence the stock used is expensive and was difficult to procure during war time. As a result square bar was tried successfully in the process. In this case allowance is made for the escape of gases ahead of the punch by having a longitudinal hole in the punch. Sometimes this hole is replaced by several smaller holes resulting in the so-called salt shaker punch. The advantage of this kind of a punch is that in case excessive pressures are built up ahead of the punch instead of the metal extruding back into a single large gas escape hole to form a pencil of steel it tends to be chilled by being forced into several smaller holes and thus doesn't create long pencils of steel at the base of the shell forging, but small mounds of metal. These small mounds of metal are beaten back into the base metal by a hammer while the forging is hot. In the case where a long pencil of steel is formed, a special tool is required to cut it off since hammering

would cause a lap. The stump is then hammered into the base.

Below are some sketches of progressive piercing with and without a collar for the first two passes only to indicate their differences.



FORGING WITHOUT COLLAR



FORGING WITH COLLAR

Pierce Hammer and Draw Method

This method of making the shell forgings was a make shift arrangement of existing equipment brought by the exigencies of war. No general adoption of the method was found in industry, but its process produces shells in a spectacular fashion. Essentially the process can be broken down into the following steps: First, a crank press pre-pierces the slug; an inverted die pot is used here. Secondly, after descaling, a steam hammer finishes the piercing with several blows. Thirdly, another crank press pushes the blank through a die which serves both as a draw ring and trimming die.

In the first step the slug used is of square cross section and rounded corners. A pair of prongs holds the slug in an upright and vertical position on top of the water cooled punch. An inverted die pot descends to make the first partial piercing. The prongs automatically are taken out of the way of the die pot as it descends. The slug rises with the die pot in which it sticks after the piercing.

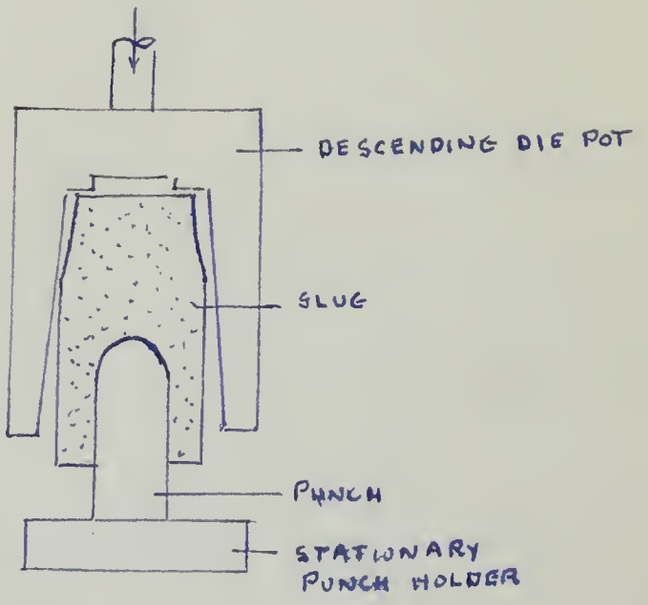
The slug is then ejected and sent to a steam hammer. Enroute it is descaled manually. The half-pierced slug is then inverted and placed in the stationary bottom die of the steam hammer. The hammer also carries with it the upper part of the die so that after the hammer has made several strokes the two parts of the die come together and the forging is complete. A flash is produced around the forging where the

top and bottom parts of the die come together.

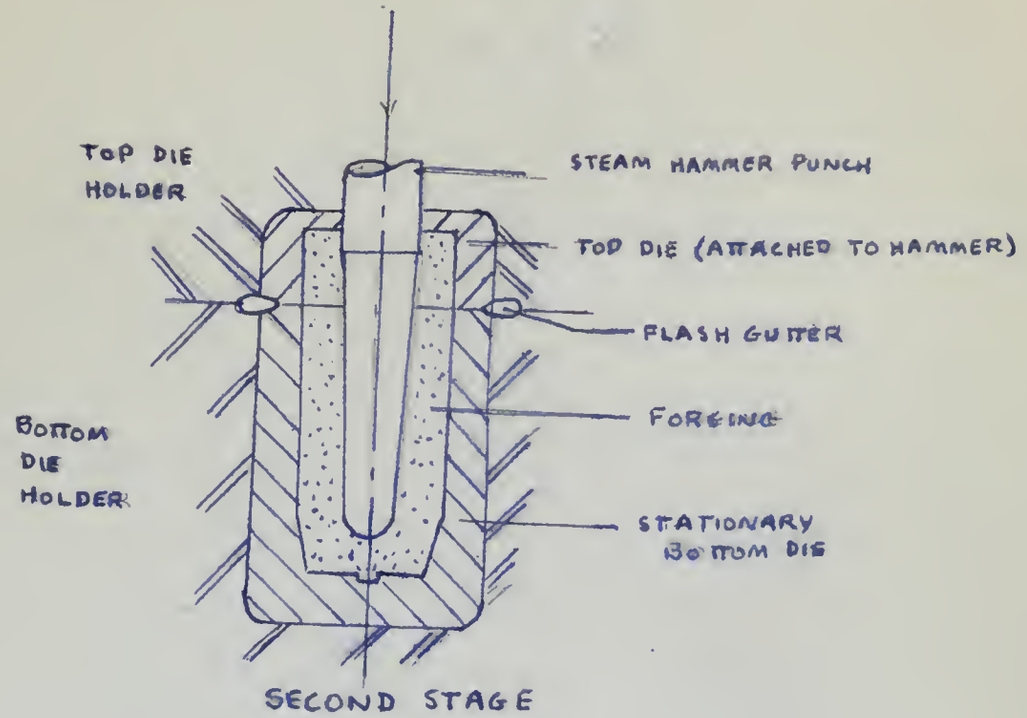
After removal of the blank from the die pot, water is sprayed on its base to harden it for the subsequent operation. The blank is then taken to another crank press where the punch acts as a mandrel and forces the blank through a draw ring designed to trim the flash mentioned previously and to draw the shell to finished size.

At first the process had high scrap losses, but later with more experience, scrap losses were reduced to a minimum.

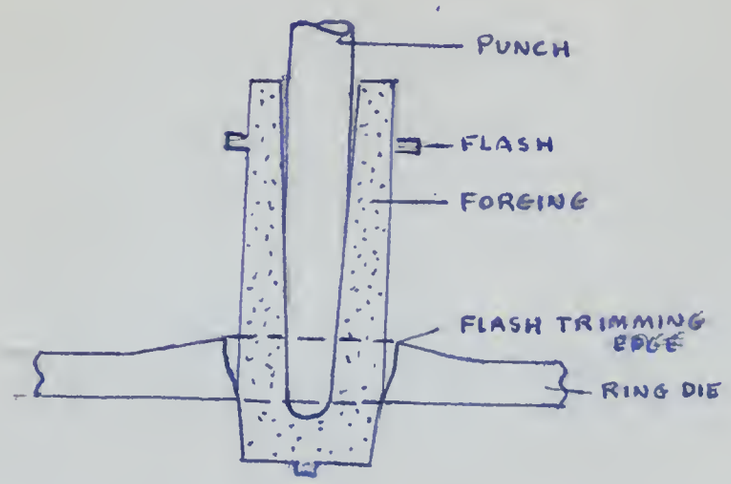
The three stages of the process areindicated schematically below.



FIRST STAGE

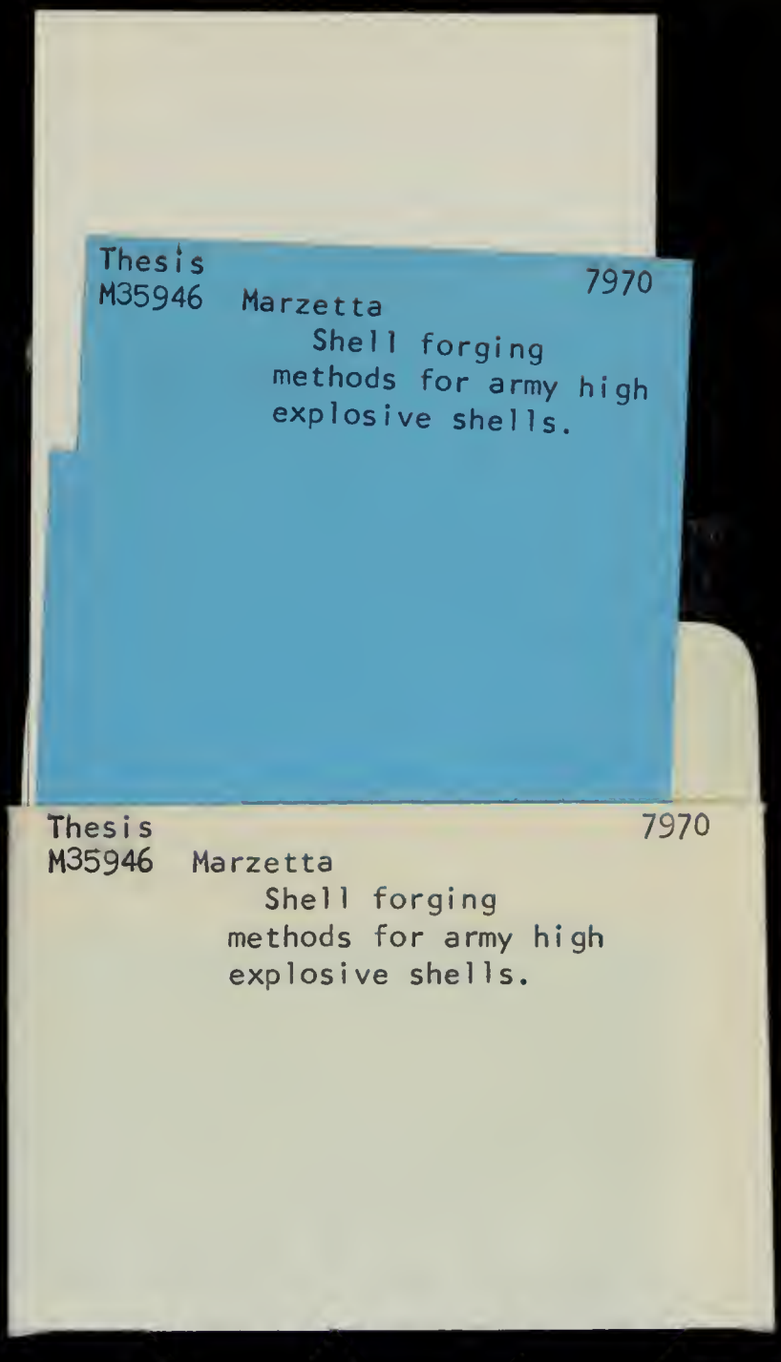


SECOND STAGE



THIRD STAGE
OF
PIERCE HAMMER AND DRAW
PROCESS

DATE DUE


Thesis
M35946 Marzetta
Shell forging
methods for army high
explosive shells.
7970
Thesis
M35946 Marzetta
Shell forging
methods for army high
explosive shells.
7970

thesM35946
Shell forging methods for army high expl
3 2768 002 12482 8
DUDLEY KNOX LIBRARY